

Claims:

1. A system for controlling an active suspension of a vehicle, having a bounce transmissibility, a roll transmissibility, and a pitch transmissibility, where the bounce, pitch, and roll transmissibilities vary with respect to a frequency of vibration acting upon the vehicle, the system comprising:

a tunable device configured for adjusting stiffness and damping of the active suspension; and

a controller in communication with the tunable device, the controller being configured to sense the frequencies of vibration and provide a control signal to the tunable device, wherein the control signal is based on a bounce component, a roll component, and a pitch component dependent on minimization of the bounce, pitch, and roll transmissibility at the sensed frequency.

2. The system according to claim 1, wherein the tunable device is a strut.

3. The system according to claim 2, wherein the tunable device is a compressible fluid strut.

4. The system according to claim 1, wherein the control signal includes a ride control component, a handling control component, and a dive/squat control component.

5. The system according to claim 4, wherein the control signal is based on the relationship

$$\begin{aligned} \text{ControlSignal} = & \beta_1 \times \text{TotalRideControl} \\ & + \beta_2 \times \text{HandlingControl} \\ & + \beta_3 \times \text{DiveSquatControl} \end{aligned}$$

where β_i are coefficients calculated based on the frequency of vibration and a summation of β_i is 1.

6. The system according to claim 4, wherein the ride control component includes a bounce control component, a roll control component, and a pitch control component.

7. The system according to claim 6, wherein the ride control is based on the relationship

$$\begin{aligned} \text{RideControl} = & \alpha_1 \times \text{BounceRideControl} \\ & + \alpha_2 \times \text{PitchRideControl} \\ & + \alpha_3 \times \text{RollRideControl} \end{aligned}$$

where α_i are coefficients calculated based on the frequency of vibration and a summation of α_i is 1.

8. The system according to claim 1, wherein the controller includes a plurality of control strategies corresponding to a plurality of frequency ranges, and the control signal is based on a control strategy of the plurality of control strategies

corresponding to a frequency range of the plurality of frequency ranges that includes the frequency of vibration.

9. The system according to claim 8, wherein the plurality of frequency ranges includes a low frequency range, a body mode frequency range, a medium frequency range, a wheel hop frequency range, and a high frequency range.

10. The system according to claim 8, wherein the plurality of control strategies includes a passive suspension control strategy, a small stiffness and skyhook control strategy, a low damping control strategy, a high damping control strategy and stiff suspension strategy.

11. The system according to claim 10, wherein the bounce control component is based on the relationship

$$\begin{aligned} \text{BounceControlComponent} = & \frac{A_1}{\varepsilon + \sum_{i=1}^5 A_i} \times \text{PassiveSuspension} \\ & + \frac{A_2}{\varepsilon + \sum_{i=1}^5 A_i} \times \text{Soft_StiffnessControl} + \frac{A_2}{\varepsilon + \sum_{i=1}^5 A_i} \times \text{SkyhookControl} \\ & + \frac{A_3}{\varepsilon + \sum_{i=1}^5 A_i} \times \text{LowDamping} \\ & + \frac{A_4}{\varepsilon + \sum_{i=1}^5 A_i} \times \text{HighDamping} \end{aligned}$$

$$+ \frac{A_5}{\varepsilon + \sum_{i=1}^5 A_i} \times LowDamping$$

where A_i are estimated amplitudes of the bounce acceleration for the corresponding frequency ranges, wherein A_1 corresponds to the low frequency range, A_2 corresponds to the body mode frequency range, A_3 corresponds to the medium frequency range, A_4 corresponds to the wheel hop frequency range, and A_5 corresponds to the high frequency range, and ε is a small number selected to avoid singularity.

12. The system according to claim 8, wherein the pitch control component is based on the relationship

$$\begin{aligned} PitchControlComponent = & \frac{A_1}{\varepsilon + \sum_{i=1}^5 A_i} \times PassiveSuspension \\ & + \frac{A_2}{\varepsilon + \sum_{i=1}^5 A_i} \times Soft_StiffnessControl + \frac{A_2}{\varepsilon + \sum_{i=1}^5 A_i} \times SkyhookControl \\ & + \frac{A_3}{\varepsilon + \sum_{i=1}^5 A_i} \times LowDamping \\ & + \frac{A_4}{\varepsilon + \sum_{i=1}^5 A_i} \times HighDamping \\ & + \frac{A_5}{\varepsilon + \sum_{i=1}^5 A_i} \times LowDamping \end{aligned}$$

where A_i are estimated amplitudes of the pitch acceleration for the corresponding frequency ranges, wherein A_1 corresponds to the low frequency range, A_2 corresponds to the body mode frequency range, A_3 corresponds to the medium frequency range, A_4 corresponds to the wheel hop frequency range, and A_5 corresponds to the high frequency range, and ε is a small number selected to avoid singularity.

13. The system according to claim 8, wherein the roll control component is based on the relationship

$$\begin{aligned}
 RollControlComponent = & \frac{A_1}{\varepsilon + \sum_{i=1}^5 A_i} \times PassiveSuspension \\
 & + \frac{A_2}{\varepsilon + \sum_{i=1}^5 A_i} \times Soft_StiffnessControl + \frac{A_2}{\varepsilon + \sum_{i=1}^5 A_i} \times SkyhookControl \\
 & + \frac{A_3}{\varepsilon + \sum_{i=1}^5 A_i} \times LowDamping \\
 & + \frac{A_4}{\varepsilon + \sum_{i=1}^5 A_i} \times HighDamping \\
 & + \frac{A_5}{\varepsilon + \sum_{i=1}^5 A_i} \times LowDamping
 \end{aligned}$$

where A_i are estimated amplitudes of the roll acceleration for the corresponding frequency ranges, wherein A_1 corresponds to the low frequency range, A_2 corresponds to the body mode frequency range, A_3 corresponds to the medium frequency range, A_4 corresponds to the wheel hop frequency range, and A_5

corresponds to the high frequency range, and ε is a small number selected to avoid singularity.